



NOAA Space Weather Products in Support of Satellite Anomaly Mitigation and Assessment

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NOAA NGDC

Satellite Anomaly Mitigation Stakeholders Meeting

April 23, 2012

NOAA SWx Products for Satellite Anomaly Mitigation and Assessment



- We welcome feedback on current and future products
- Your feedback is important so that we can prioritize the products that you, our customers, need
- Feedback opportunities today:
 - Ballot on future products
 - Up next: panel discussion

Vote!



Vote!





Outline

- Current NOAA products
- New products under development
- Candidate new products

NOAA Space Weather Warnings, Alerts & Summaries

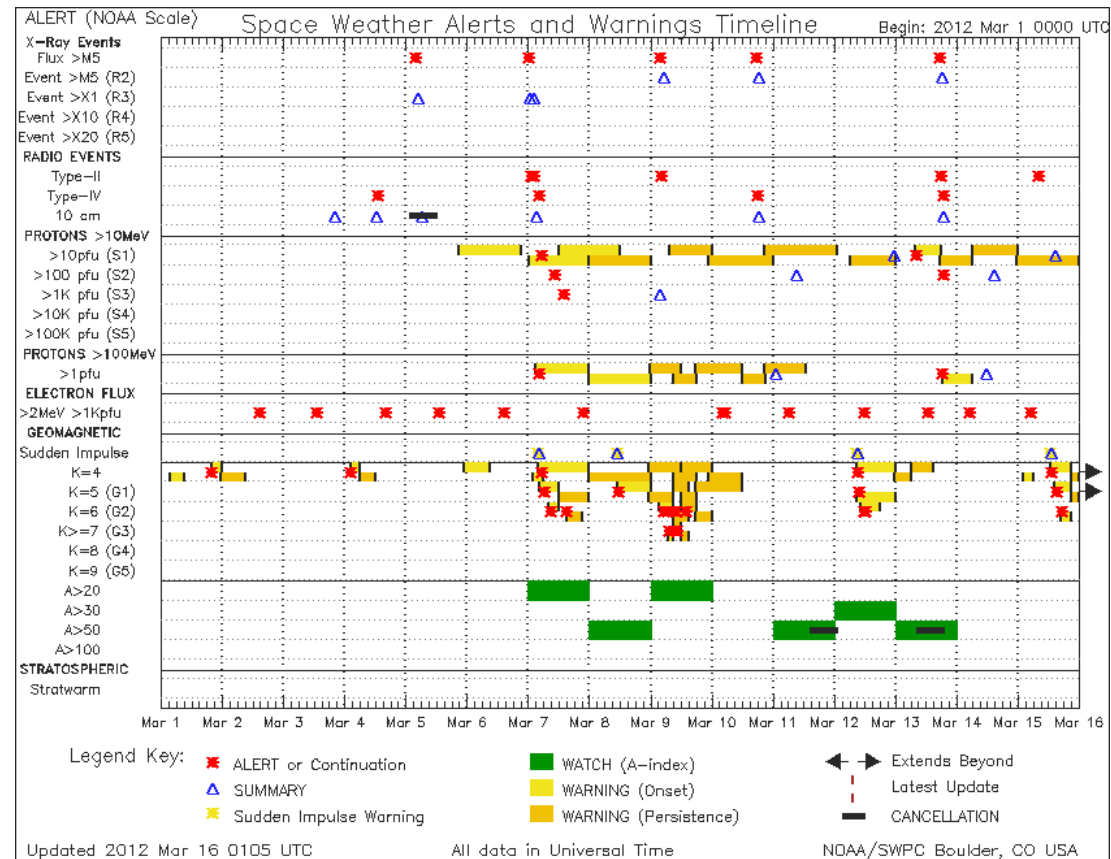


- Solar x-ray and radio
- Solar proton fluxes
- MeV electron fluxes
- Geomagnetic sudden impulse & indices

warning: forecast

alert: nowcast

summary: after the event



Current: <http://www.swpc.noaa.gov/alerts/archive.html>

Archive: http://www.swpc.noaa.gov/alerts/warnings_timeline.html

To subscribe:

<https://pss.swpc.noaa.gov/LoginWebForm.aspx?ReturnUrl=%2fproductssubscriptionservice%2f>

NOAA Real-Time Geophysical Data Lists



- GOES magnetic field
 - GOES solar proton and MeV electron integral fluxes
 - GOES solar proton and MeV electron daily fluences
 - GOES solar proton channel fluxes
 - GOES keV electron and proton fluxes
- NEW FOR GOES 13-15***



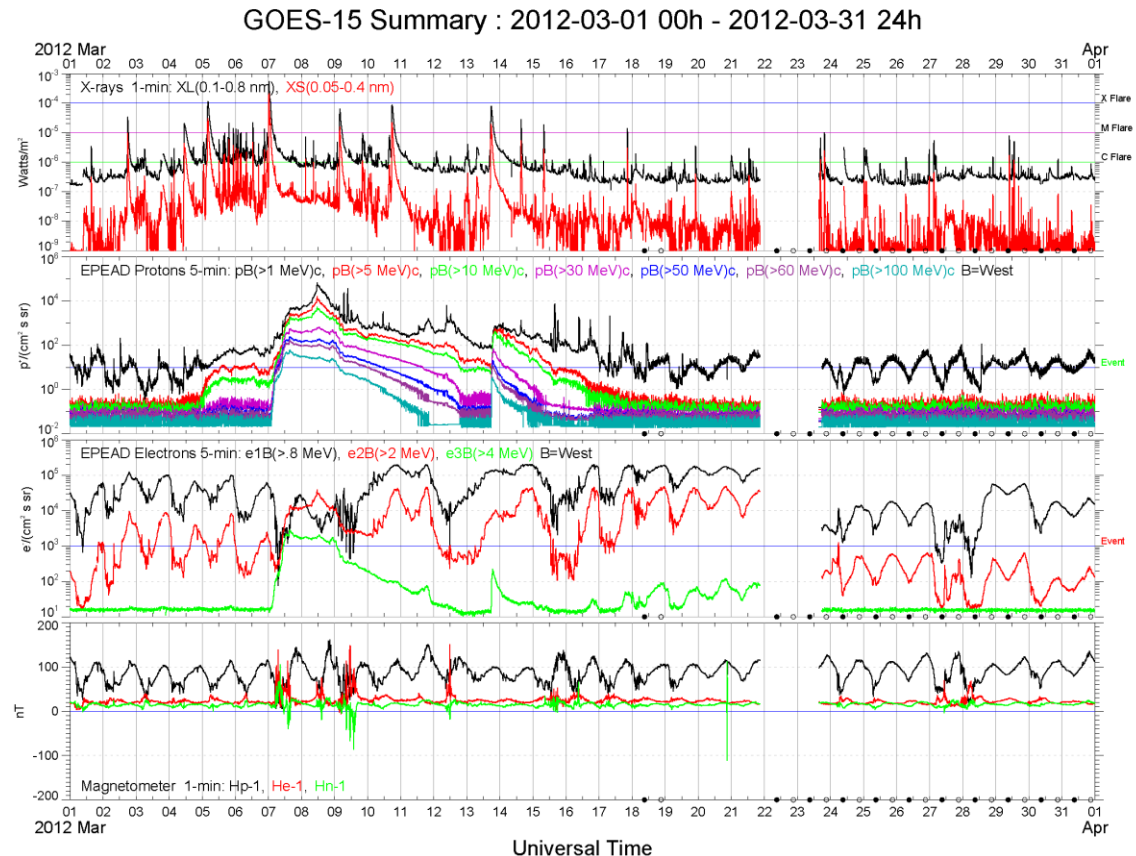
- POES energetic particle belt indices
- K and A indices
- USAF Kp and Wing Kp

Anonymous FTP: <http://www.swpc.noaa.gov/ftpmenu/lists.html>

Retrospective Space Weather Data from NOAA and DoD Satellites



- SWPC provides a critical subset of the GOES SWx data in real-time via the Data Lists
- Comprehensive retrospective NOAA SWx data are available from NGDC
- Documentation of the instruments and data sets is always being augmented



GOES SEM: <http://www.ngdc.noaa.gov/stp/satellite/goes/dataaccess.html>

GOES documentation: <http://www.ngdc.noaa.gov/stp/satellite/goes/documentation.html>

POES/MetOp SEM: <http://www.ngdc.noaa.gov/stp/satellite/poes/index.html>

DMSP SWx: <http://www.ngdc.noaa.gov/nndc/struts/results?t=102827&s=1&d=1001,1002,9>



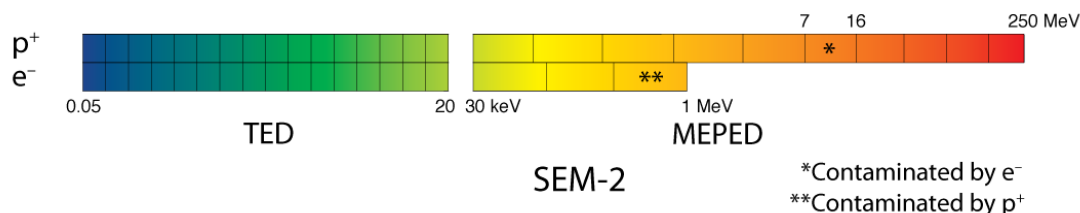
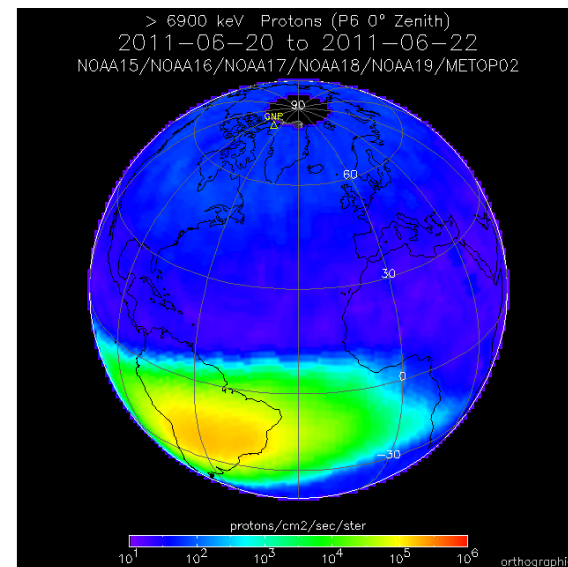
Outline

- Current NOAA products
- **New products under development**
- Candidate new products

New Products Under Development: POES / MetOp SEM-2 (Re)processing



- NGDC now receives SEM raw data files directly from OSPO and archives them
- Real-time processing being transitioned from SWPC to NGDC
- NGDC will process/reprocess the POES and MetOp data using mostly new code, with certain science improvements:
 - Fluxes calculated in real-time
 - Magnetic parameters (e.g., pitch angles) calculated using IGRF at proper epoch
- MetOp B launch scheduled 23 May 2012, data available 7 June



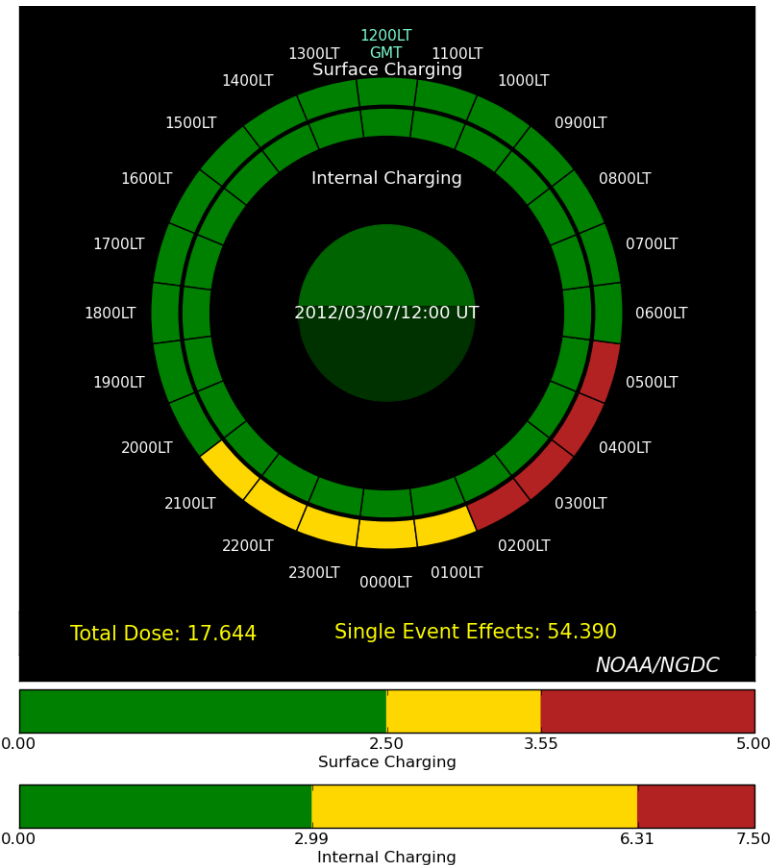
New Products Under Development: Space Environmental Anomalies



Expert System Real Time (SEAESRT)

- Provides hazard quotients (probability ratio) for 4 types of anomalies in geosynchronous orbit
- Hazard quotient of 1 corresponds to mission-averaged probability

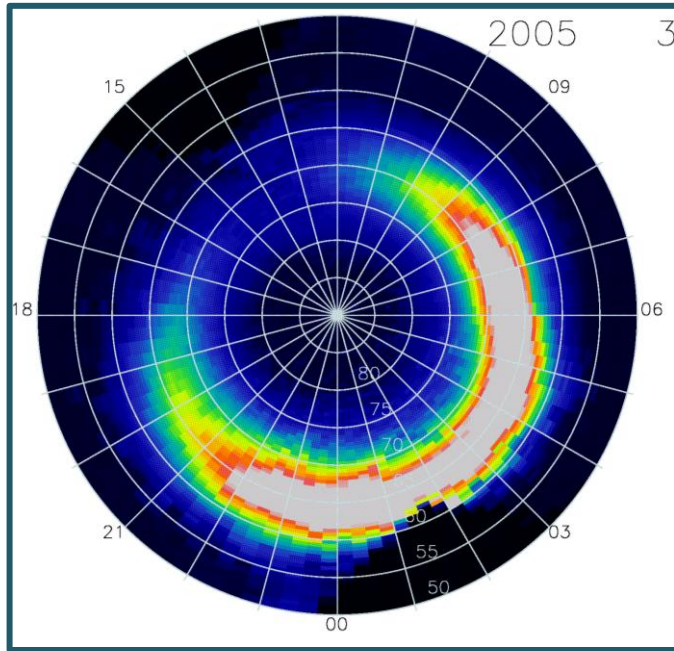
Hazard	Data Source
Surface charging	USAF <i>Kp</i>
Internal charging	12-hr average of GOES >2 MeV electron flux
Single-event effects (SEP)	GOES >30 MeV solar protons
Total dose, solar arrays	GOES >5 MeV solar protons



O'Brien, T. P. (2009), SEAES-GEO: A spacecraft environmental anomalies expert system for geosynchronous orbit, *Space Weather*, 7, S09003, doi:10.1029/2009SW000473.

See SWx Workshop poster: J. Darnel et al.,
"Implementation of Space Environmental Anomalies
Expert System Real Time"

New Products under Development: OVATION Prime



- Implementation of Newell OVATION Prime
- NGDC: forecast auroral energy deposition
 - Real-time, user-configurable, science-validated (Machol et al., 2012)
 - Public access via SourceForge
- Research to operations at SWPC: forecast visible aurora location

Machol, J.L., J.C. Green, R.J. Redmon, R.A. Viereck, and P.T. Newell (2012), Evaluation of OVATION Prime as a Forecast Model for Visible Aurorae, *Space Weather*, 10, S03005, doi:10.1029/2011SW000746.

SourceForge Find Open Source Software Browse Blog Support Jobs Resources

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OVATION Prime
jmachol, redmon

Seasonal model of the diffuse, monoenergetic, proton, and wave aurora.

Add a Review
27 Downloads (This Week)

Download
ovation_prime_2.0.0.zip

Browse All Files

Update screenshots

Description

OVATION Prime is a seasonal model of the diffuse, monoenergetic, proton, and wave aurora.

The OVATION Prime model is written in IDL and was developed at the Johns Hopkins Applied Physics Laboratory (JHU-APL) by Patrick Newell and co-workers. Documentation in the downloadable zip file includes a model description and instructions for running the software.

A web interface for running the model for historical periods is available here:
http://sd-www.jhuapl.edu/Aurora/ovation_prime/prime_display.html

Realtime versions are running here:
http://www.ngdc.noaa.gov/stp/ovation_prime/
<http://helios.swpc.noaa.gov/ovation/>

***Is there interest in tailoring this for satellite
anomaly assessment purposes?***



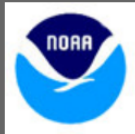
Outline

- Current NOAA products
- New products under development
- **Candidate new services and products**

Candidate Service: Satellite Portal for Anomaly Analysis Data



“One Stop Shopping”



Portal for Satellite Anomaly Analysis Data (PSAAD)

- [Home](#)
- [Background Information](#)
- [Surface Charging Data](#)
- [Internal Charging Data](#)
- [Single Event Upsets Data](#)
- [Total Dose Degradation Data](#)
- [Resources](#)
- [References](#)

PSAAD

PSAAD is a portal to data valuable for determining whether a satellite malfunction is likely related to changes in the space radiation environment. The portal provides particle radiation related to 4 types of common anomalies: surface charging, internal charging, single event upsets, and total dose degradation. (See the Background Information for more about the different types of anomalies). The data are presented in real time plots along with links for retrieving data files.



[Current Space Weather Alerts](#)

[Recent Significant Event Reports](#)

Candidate Product: Space Weather Large Event Reports



Rapid brief reports for NOAA and satellite customers on the *environmental conditions* during solar or geomagnetic storms in which the *likelihood* of satellite anomalies due to space weather may be increased

Space Weather Conditions at the Time of the Galaxy 15 Spacecraft Anomaly

Report of the
NOAA Tiger Team

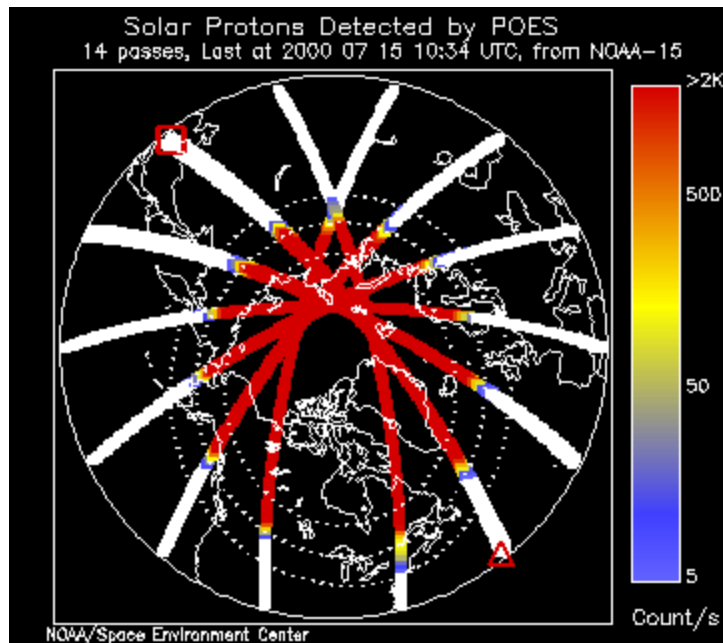
Boulder, CO

01 June 2010



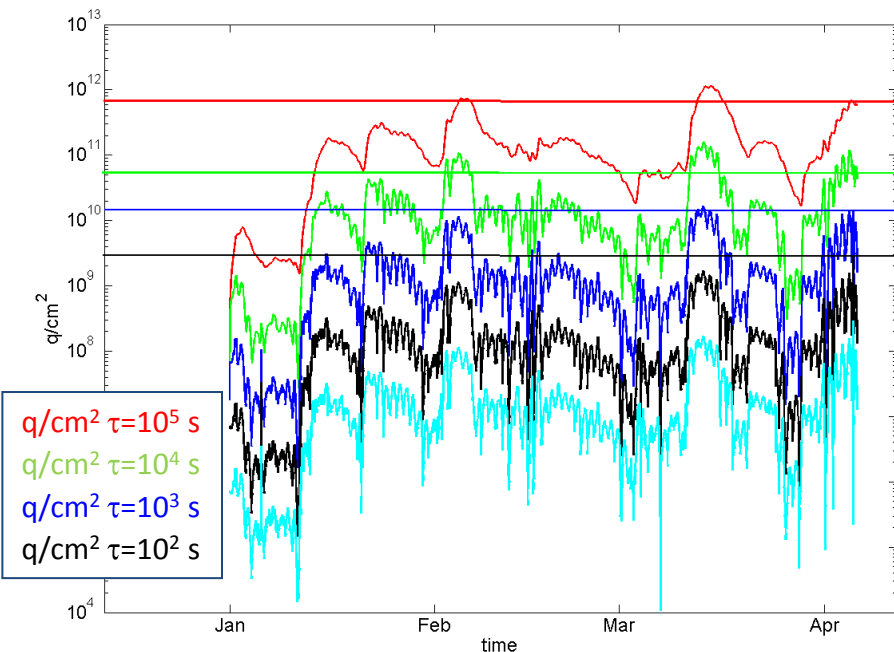
Galaxy 15 satellite. Photo Credit: Orbital Sciences

Candidate Product: Maps and Mappings of POES Solar Proton Fluxes



- Uses real-time fluxes produced by POES/MetOp SEM-2 Processing to determine the latitudinal extent of solar proton fluxes at low altitudes
- Primarily an ON/OFF product
- For LEO spacecraft: map of solar proton fluxes in the polar cap from observations by multiple SEM-2 on POES and MetOp satellites
- For satellites in higher orbits: mapping of the satellite location to the polar cap fluxes using magnetic field models driven by real-time solar wind or magnetospheric parameters

Candidate Product: Accumulated Charge for Deep Dielectric Charging Assessment



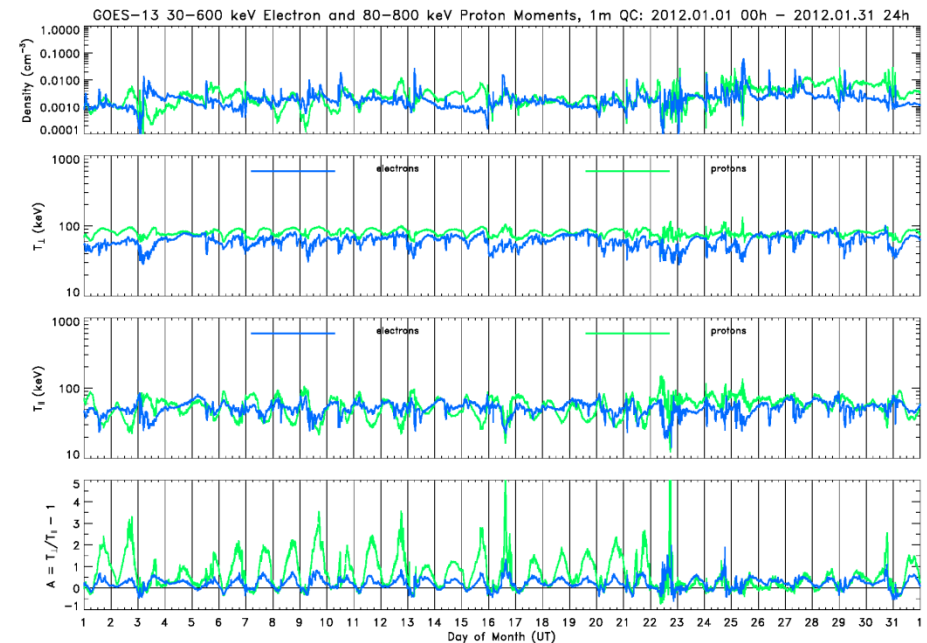
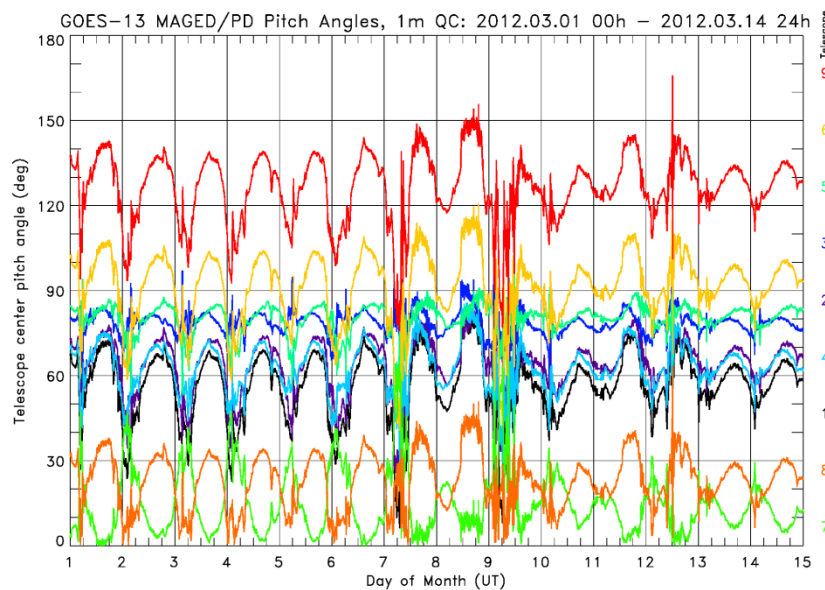
Accumulated charge calculated at GOES 14 in early 2010 using measured >350 keV electron flux for different dielectric discharge time constants

- Accumulated charge, rather than flux or fluence, drives the risk for electrostatic discharges due to deep charging (Bodeau, 2010)
- As a rule of thumb, an accumulated charge of 10^{10} to 10^{11} q/cm² can induce internal discharges within spacecraft (q = electronic charge)
- Dielectric time constants, τ , for typical dielectric material range from 10 to 10^5 s (Garrett and Whittlesey, 2000)
- τ can be years (Bodeau, 2010)
- The candidate product would calculate accumulated charge from real-time GOES fluxes over a wide range of dielectric time constants and electron threshold energies
- Real-time and retrospective

Bodeau, M., High energy electron climatology that supports deep charging risk assessment in GEO, 48th AIAA Aerospace Sciences Meeting, Orlando, Florida, AIAA 2010-1608, 2010.

Garrett, H.B. and A.C. Whittlesey, Spacecraft Charging, An Update, IEEE Trans. on Plasma Sci., 28, p 2017, 2000.

Candidate Product: GOES 13-15 MAGED/PD Pitch Angles and Moments in Real Time

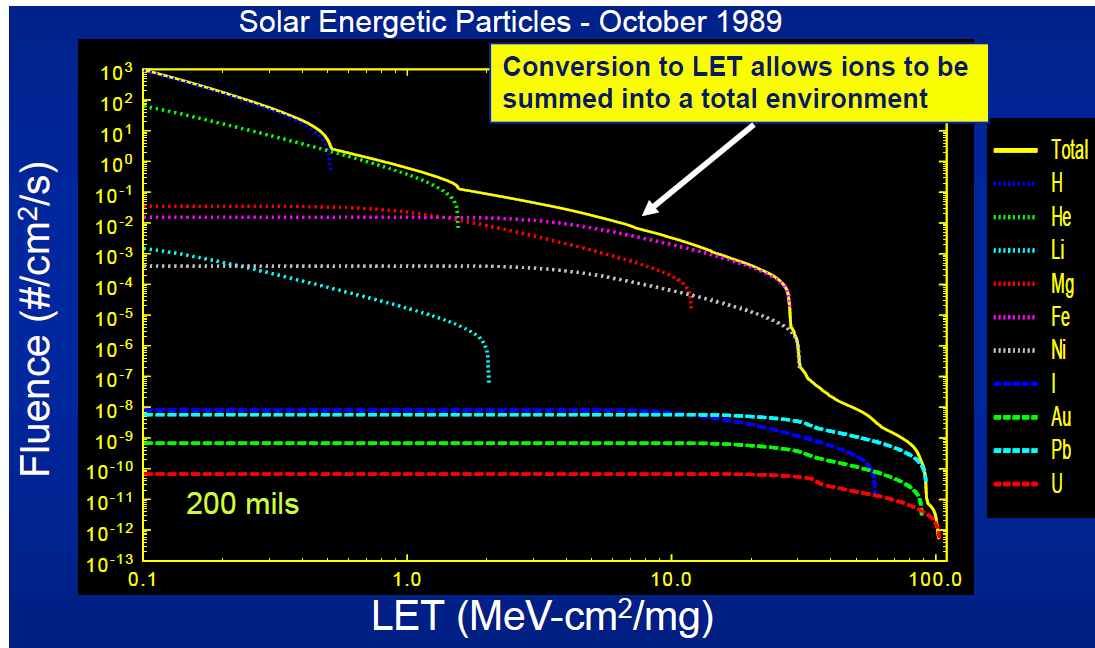


Currently produced retrospectively:

http://satdat.ngdc.noaa.gov/sem/goes/data/new_avg/
e.g., 'g13_moments_1m_20120101_20120131.nc'

See SWx Workshop poster: D. P. Hartley et al., "Electron observations at GEO during the high speed stream (HSS) commencing on January 6th, 2011"

Candidate Product: Linear Energy Transfer from GOES-R+ Energetic Heavy Ion Fluxes



From Workshop on Energetic Particle Measurements from GOES R+ Satellites (28-29 October 2002), contribution by J. Barth

- GOES-R+ EHIS will measure $Z = 1-28$ with elemental resolution over $\sim 20-500 \text{ MeV/nuc}$ in 5 energy bands
- Fluxes are the required GOES-R+ EHIS product
- GOES-R+ Workshop (2002) recommended LET for various shielding thicknesses as a product

**Would you like to have LET in real-time from GOES-R+ EHIS?
Would you like to have a probability of upset?**



Other Candidate Products

- GOES magnetic fields in VDH, GSE and GSM coordinates
- Magnetopause crossings from GOES and ACE observations
- GOES solar proton event fluences (>10 , 30, 60, 100 MeV), in progress and total
- Error bars on charged particle fluxes
- Galactic cosmic rays from POES and GOES
- Global physics-based radiation belt model with data assimilation



Summary

- We welcome feedback on current and future products
- Your feedback is important so that we can prioritize the products that you, our customers, need
- Feedback opportunities this week:
 - Ballot on future products
 - Up next: panel discussion
 - Tuesday morning session on “Space Weather Effects on Satellites” (9:30-12), including Satellite Roundtable Discussion
 - Visit us at our posters:
 - J. Darnel et al., “Implementation of Space Environmental Anomalies Expert System Real Time”
 - J. Rodriguez et al., “New space weather particle and magnetic field products at NGDC”

Vote!



Vote!



Space Weather Data at COSPAR 2012



- During the COSPAR Scientific Assembly (14-22 July 2012, Mysore, India) the COSPAR Panel on Space Weather will be convening three events:

PSW1: Space Weather: Fundamental Physics to Operational Forecasting

PSW2: Cross-disciplinary challenges in Space Situational Awareness

PSW3: Space Weather Data, Observations and Exploitation for Research and Applications

- **PSW3: Space Weather Data, Observations and Exploitation for Research and Applications**

Many space weather services rely on data from scientific missions. Data provided by these missions is of extremely high quality, however, missions are developed with a set of primary scientific goals and no replacement strategy at end of life. Timeliness of data delivery may also not be a priority.

Conversely, valuable scientific work may be based on data from monitoring instrumentation which is often designed to provide coarser measurements, with an emphasis on timeliness of data delivery and continuity should a particular instrument fail. This continuity leads to the generation of longer term datasets, which provide information on timescales not otherwise available.

In a third scenario, scientific measurements may be affected by space weather, necessitating a correction to the primary data which itself may provide valuable information on current conditions.

This session will review current data availability and discuss issues involved in developing services based on scientific data and using long term datasets designed primarily for monitoring in scientific studies. Key measurement parameters will also be highlighted.

MSO: Alexi Glover, ESA

DSO: Daniel Heynderickx (DH Consultancy), Larisa Trichtchenko (N R Canada)



Backup Charts

SWPC Warnings and Alerts:

Geomagnetic



Phenomenon	Product	Contents	Supporting Data
Sudden Impulse	Warning	Geomagnetic Sudden Impulse expected	ACE solar wind plasma (shock)
	Summary	Geomagnetic Sudden Impulse	Mid- and low-latitude and GOES magnetometers
K-index	Warning	Geomagnetic K-index of (4, 5, 6, 7 or greater) expected	ACE
	Alert	Geomagnetic K-index of: 4 (Minor system effects) 5 (G1 geomagnetic storm) 6 (G2 geomagnetic storm) 7 (G3 geomagnetic storm) 8 (G4 geomagnetic storm) 9 (G5 geomagnetic storm)	7 magnetometers (USGS, BGS, IPGP) plus 3 planned (Geoscience Australia, Geological Survey of Canada)

SWPC Warnings and Alerts: Proton Fluxes



Phenomenon	Product	Contents	Supporting Data
Proton 10 MeV Integral Flux	Warning	Proton 10 MeV Integral Flux above 10 pfu expected	X-ray flare; ACE and GOES proton fluxes
	Alert	Proton Event 10 MeV Integral Flux exceeded: 10 pfu (S1 solar radiation storm) 100 pfu (S2 solar radiation storm) 1000 pfu (S3 solar radiation storm) 10000 pfu (S4 solar radiation storm) 100000 pfu (S5 solar radiation storm)	GOES derived integral proton fluxes
	Summary	Proton Event 10 MeV Integral Flux exceeded: 10 pfu (S1 solar radiation storm) 100 pfu (S2 solar radiation storm) 1000 pfu (S3 solar radiation storm) 10000 pfu (S4 solar radiation storm) 100000 pfu (S5 solar radiation storm)	GOES derived integral proton fluxes

SWPC Warnings and Alerts: Proton and Electron Fluxes



Phenomenon	Product	Contents	Supporting Data
Proton 100 MeV Integral Flux	Warning	Proton 100 MeV Integral Flux above 1 pfu expected	X-ray flare; ACE and GOES proton fluxes
	Alert	Proton Event 100 MeV Integral Flux exceeded 1 pfu	GOES derived integral fluxes
	Summary	Proton Event 100 MeV Integral Flux exceeded 1 pfu	GOES derived integral fluxes
Electron 2 MeV Integral Flux	Alert	Electron 2 MeV Integral Flux exceeded 1000 pfu	GOES EPEAD E2 channel

NOAA Space Weather Warnings, Alerts & Summaries: Examples



Space Weather Message Code: SUMSUD
Serial Number: 146
Issue Time: 2012 Mar 07 0429 UTC

SUMMARY: Geomagnetic Sudden Impulse
Observed: 2012 Mar 07 0427 UTC
Deviation: 20 nT
Station: Boulder

Space Weather Message Code: ALTPC0
Serial Number: 35
Issue Time: 2012 Mar 07 0416 UTC

ALERT: Proton Event 100MeV Integral Flux exceeded 1pfu
Begin Time: 2012 Mar 07 0405 UTC
Potential Impacts: An enhancement in the energetic portion of the solar radiation spectrum may indicate increased biological risk to astronauts or passengers and crew in high latitude, high altitude flights. Additionally, energetic particles may represent an increased risk to all satellite systems susceptible to single event effects. This information should be used in conjunction with the current Solar Radiation Storm conditions when assessing overall impact.

Space Weather Message Code: WARK05
Serial Number: 750
Issue Time: 2012 Mar 07 0355 UTC

WARNING: Geomagnetic K-index of 5 expected
Valid From: 2012 Mar 07 0415 UTC
Valid To: 2012 Mar 07 1200 UTC
Warning Condition: Onset
NOAA Scale: G1 - Minor
Potential Impacts: Area of impact primarily poleward of 60 degrees Geomagnetic Latitude.
Induced Currents - Weak power grid fluctuations can occur.
Spacecraft - Minor impact on satellite operations possible.
Aurora - Aurora may be visible at high latitudes, i.e., northern tier of the U.S. such as northern Michigan and Maine.

SWPC Lists of Solar-Geophysical Data



List	Cadence	Timeli- ness	Contents	Sources (as of 23 April 2012)
GOES Energetic Proton and Electron Data	5 min	Real-time	Integral fluxes: 7 proton (>1, 5, 10, 30, 50, 100 MeV) 3 electron (>0.8, 2, 4 MeV)	GOES 13, 15
GOES Proton Channel Data	5 min	Real-time	Differential fluxes: 11 channels, 0.7->700 MeV (7 from EPEAD, 4 from HEPAD)	GOES 13, 15
GOES Magneto-spheric Particles	1 min	Real-time	Differential fluxes: 30-600 keV electrons, 80-800 keV protons (5 energies, 9 telescopes)	GOES 13, 15
GOES Magnetometer	1 min	Real-time	Hp, He, Hn, total field	GOES 13, 15

SWPC Lists of Solar-Geophysical Data



List	Cadence	Contents	Sources (as of 23 April 2012)
GOES Daily Fluences	Daily	Proton (>1, 10, 100 MeV) and electron (>0.8, 2 MeV) daily fluences	GOES 13
POES Energetic Particle Belt Indices	Daily	4 indices (total, inner, slot, outer) by channel (22)	NOAA POES 18
Geomagnetic A and K indices	Hourly up-dates	K (3-hr) and A (daily) station indices, and Kp and Ap planetary indices	USGS stations
USAF AFWA Wing Kp	15 min	1-hr and 4-h advance prediction	Forecast based on ACE (L1) solar wind plasma and magnetic field data

NOAA Real-Time Geophysical Data Lists: Example (Integral Fluxes)

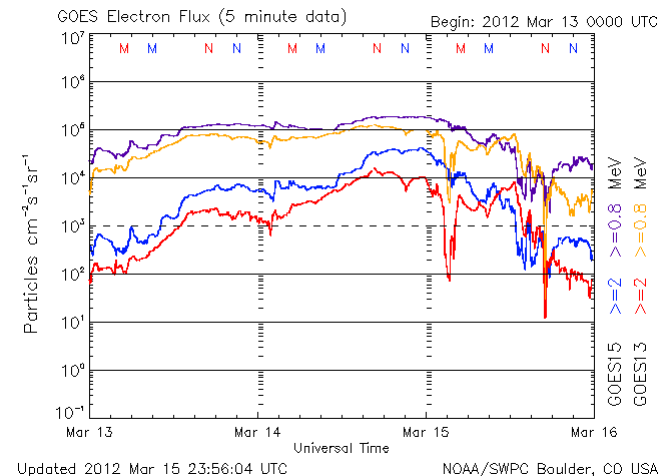
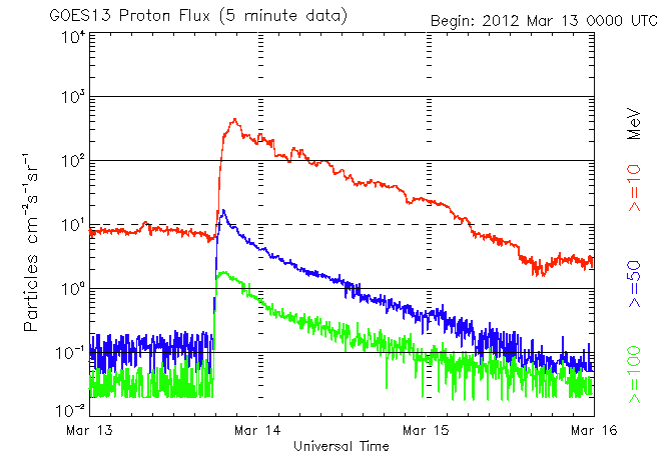


```
:Data_list: 20120313_Gp_part_5m.txt
:Created: 2012 Mar 14 0011 UTC
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center
# Please send comments and suggestions to SWPC.Webmaster@noaa.gov
```

```
#
# Label: P > 1 = Particles at >1 Mev
# Label: P > 5 = Particles at >5 Mev
# Label: P >10 = Particles at >10 Mev
# Label: P >30 = Particles at >30 Mev
# Label: P >50 = Particles at >50 Mev
# Label: P>100 = Particles at >100 Mev
# Label: E>0.8 = Electrons at >0.8 Mev
# Label: E>2.0 = Electrons at >2.0 Mev
# Label: E>4.0 = Electrons at >4.0 Mev
# Units: Particles = Protons/cm2-s-sr
# Units: Electrons = Electrons/cm2-s-sr
# Source: GOES-13
# Location: W075
# Missing data: -1.00e+05
```

5-minute GOES-13 Solar Particle and Electron Flux

#	UTC Date		Time	Modified Seconds		P > 1	P > 5	P >10	P >30	P >50	P>100	E>0.8	E>2.0	E>4.0
#	YR	MO	DA	HHMM	Julian Day									
#														
2012	03	13	0000	55999	0	3.12e+02	3.08e+01	8.11e+00	2.61e-01	7.23e-02	2.72e-02	5.51e+03	7.92e+01	-1.00e+05
2012	03	13	0005	55999	300	3.49e+02	3.29e+01	8.86e+00	4.57e-01	1.39e-01	4.33e-02	4.61e+03	6.37e+01	-1.00e+05
2012	03	13	0010	55999	600	3.58e+02	2.88e+01	7.01e+00	2.91e-01	9.35e-02	4.51e-02	4.87e+03	6.80e+01	-1.00e+05
*														
*														
2012	03	13	2100	55999	75600	7.46e+02	6.23e+02	4.10e+02	4.18e+01	9.44e+00	1.49e+00	7.12e+04	1.62e+03	-1.00e+05
2012	03	13	2105	55999	75900	7.17e+02	5.91e+02	3.73e+02	3.83e+01	8.76e+00	1.33e+00	7.12e+04	1.74e+03	-1.00e+05
2012	03	13	2110	55999	76200	7.01e+02	5.77e+02	3.62e+02	3.47e+01	7.94e+00	1.31e+00	7.31e+04	1.90e+03	-1.00e+05
2012	03	13	2115	55999	76500	7.30e+02	6.01e+02	3.66e+02	3.29e+01	7.68e+00	1.37e+00	7.46e+04	1.90e+03	-1.00e+05
2012	03	13	2120	55999	76800	7.58e+02	6.17e+02	3.68e+02	3.24e+01	7.48e+00	1.32e+00	7.39e+04	1.96e+03	-1.00e+05
2012	03	13	2125	55999	77100	7.68e+02	6.21e+02	3.65e+02	3.11e+01	7.08e+00	1.24e+00	7.52e+04	2.11e+03	-1.00e+05
2012	03	13	2130	55999	77400	8.05e+02	6.49e+02	3.71e+02	3.15e+01	7.25e+00	1.27e+00	7.52e+04	2.16e+03	-1.00e+05
2012	03	13	2135	55999	77700	8.18e+02	6.48e+02	3.57e+02	2.81e+01	6.77e+00	1.34e+00	7.52e+04	2.16e+03	-1.00e+05
2012	03	13	2140	55999	78000	7.55e+02	5.71e+02	3.00e+02	2.78e+01	6.76e+00	1.28e+00	7.18e+04	1.76e+03	-1.00e+05
2012	03	13	2145	55999	78300	8.14e+02	6.01e+02	3.02e+02	2.70e+01	6.61e+00	1.29e+00	7.12e+04	1.77e+03	-1.00e+05
2012	03	13	2150	55999	78600	7.93e+02	5.53e+02	2.66e+02	2.79e+01	7.02e+00	1.27e+00	7.33e+04	1.61e+03	-1.00e+05
2012	03	13	2155	55999	78900	7.54e+02	5.14e+02	2.46e+02	2.68e+01	6.20e+00	8.26e-01	7.52e+04	1.75e+03	-1.00e+05
2012	03	13	2200	55999	79200	7.32e+02	4.86e+02	2.26e+02	2.74e+01	7.33e+00	1.25e+00	7.52e+04	1.86e+03	-1.00e+05
2012	03	13	2205	55999	79500	7.80e+02	5.12e+02	2.37e+02	2.64e+01	6.41e+00	9.32e-01	7.52e+04	1.80e+03	-1.00e+05
2012	03	13	2210	55999	79800	8.41e+02	5.60e+02	2.64e+02	2.60e+01	6.73e+00	1.23e+00	7.50e+04	1.91e+03	-1.00e+05
2012	03	13	2215	55999	80100	8.73e+02	5.65e+02	2.59e+02	2.58e+01	6.16e+00	9.35e-01	7.32e+04	1.85e+03	-1.00e+05
2012	03	13	2220	55999	80400	9.02e+02	5.76e+02	2.59e+02	2.48e+01	6.08e+00	9.78e-01	7.12e+04	1.91e+03	-1.00e+05
2012	03	13	2225	55999	80700	8.93e+02	5.64e+02	2.60e+02	2.33e+01	5.67e+00	9.54e-01	7.41e+04	2.06e+03	-1.00e+05



Retrospective GOES SEM Products: Full Time Resolution



- Full-resolution files start with GOES-13
- One-day files containing time series of identical cadence
- EPEAD (both eastward and westward observations)
 - 32-s alpha particles (6 channels)
 - 4-s E1 (>0.8 MeV) electrons
 - 16-s E2 (>2 MeV) and E3 (>4 MeV) electrons
 - 8-s P1 (0.7-4.2 MeV) protons
 - 32-s P2-P7 (4.2-900 MeV) protons
- HEPAD
 - 32-s protons (4 channels) and alpha particles (2 channels)
 - 4-s singles (5 channels)
- MAGED
 - 2-s 40 and 75 keV electrons (9 telescopes)
 - 4-s 150 keV electrons (9 telescopes)
 - 16-s 275 keV electrons (9 telescopes)
 - 32-s 475 keV electrons (9 telescopes)
- MAGPD
 - 16-s 95, 140 and 210 keV protons (9 telescopes)
 - 32-s 300 and 475 keV protons (9 telescopes)
- Magnetometer
 - 512-ms field components (instrument, spacecraft, PEN coordinates; total field; both magnetometers)

Retrospective GOES SEM Products: Time-Averages



- One-month files, 1-min and 5-min averages
- EPEAD (both eastward and westward observations)
 - Alpha particles (6 channels)
 - MeV electrons (3 channels)
 - MeV solar protons (7 channels)
 - Derived integral solar proton fluxes (7 thresholds)
- HEPAD
 - Protons (4 channels) and alpha particles (2 channels)
 - Singles (5 channels) (GOES 13-15)
- MAGED (GOES 13-15)
 - keV electrons (9 telescopes)
- MAGPD (GOES 13-15)
 - keV protons (9 telescopes)
- Magnetometer